SECTION 4.2

OIL & GAS PRODUCTION
VALVES AND FITTINGS

(New - November 1986; Revised - January 1990)

EMISSION INVENTORY SOURCE CATEGORY
Petroleum Production and Marketing / Oil and Gas Production

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION
310-302-1600-0000 (81968) Oil Production Fugitive Losses - Valves
310-304-1600-0000 (81976) Oil Production Fugitive Losses - Fittings

METHODS AND SOURCES

Petroleum production delivers a stream of oil and gas mixtures and leads to fugitive emissions. These fugitive losses of total organic gas (TOG) and reactive organic gas (ROG) emissions are analyzed for valves and fittings in these categories. For emission calculation purposes, fittings are classified as threaded and flanged connections.

The Air Resources Board uses emission factors for valves and fittings derived from two sources. Rockwell International[1] developed general oil and gas production emission factors based on empirical valve and fitting fugitive data; KVB Incorporated[2] based its emission factor on a 1979-80 field study to develop composite emission factors specifically for the valve and fitting components of oil production operations in California.

Because of the vast network of oil production operations located across the state of California, KVB considered it impractical to survey each oil field separately. Instead, oil fields were grouped into certain classifications based upon parameters affecting overall emissions, so that a representative number of fields were sampled. KVB chose representative production fields from each group to be studied. KVB then selected the leases within the representative fields to be surveyed. These leases represent tracts of land on which oil and gas reservoirs are found. From this survey, detailed counts were made of the number of valves and fittings in actual operation at a lease.

Using KVB's results and the Rockwell emission factors, the ARB staff has created a computer algorithm designed to calculate the distinct emission factors for six different "lease models." These lease models were created to group the leases into distinct categories for which emission

factors have been calculated. These lease models were differentiated based upon the number of wells in operation at a lease and the gas to oil ratio (GOR). The GOR is an oil production term that represents the cubic feet of hydrocarbon gas produced per barrel of oil produced. Each lease model has a computer algorithm that calculates a "per well" emission factor. The lease models are divided into classifications in which the breakpoints for the numbers of wells are set at 10 and 50, while the breakpoint for the GOR was set at 500 cubic feet per barrel. These breakpoints could be further divided from six to twelve categories, but this further division results in more complex programming and quality assurance work. Within these lease models, separate emission factors per well were developed for gas, liquid, mixture, and condensate service valves and fittings. The oil and gas samples from these lease models consisted of multiphase fluids during normal operation. Multiphase fluids are fluids that are present in combinations of phases such as liquid/gas mixtures. For example, the gas emission factor is an aggregate of the emission factors from the gas and oil produced including the gas, liquid, mixture, and condensate emission factors representing the emissions from the produced oil. Together, these four fluid phases cover all the major sources of oil production valve and fitting emissions in California. The detailed fluid phase emission factors on a "per well" basis for valves and fittings are presented in Tables II and III, respectively. These detailed fluid phase emission factors are based on studies done by KVB[2] and Rockwell.[1]

The lease model algorithms needed to be adjusted for certain situations before using the fluid phase emission factors to calculate emissions for valves and fittings. In some instances, gas was produced at a lease without oil production. In these cases, the GOR was technically equal to infinity. However, for the Air Resources Board emission estimate, the GOR was set equal to the gas production rate. The gas emission factor was used to calculate lease wide valve and fitting emissions. In another situation, the emission factors are set to zero for wells having oil with an API gravity less than 20, no gas production, and no thermal enhancement. The corresponding emissions for zero emission factors are zero for both valves and fittings.

The California Division of Oil and Gas[3] provided the lease data for 1987 which was used to determine the number of active wells on each lease in the state plus the GORs of those wells. This information was then incorporated into the lease model program, and resulting fugitive valve and fitting emissions were calculated for each lease.

After the fugitive valve and fitting emissions are calculated, adjustments in each lease are made for any maintenance performed. This maintenance is not included in the lease model algorithms; therefore, the emission factors do not reflect the resulting reduction in emissions. Some districts have rules and regulations requiring maintenance for valves and fittings, and the lease model emissions from these districts need adjustments (See Table I for more specific information).

Table I
The Effectiveness of Maintenance Operations on Valve and Fitting Emissions

County	Percent Reduction Due to Maintenance
Kern[4,5]	50
Los Angeles[6]	50
Riverside[6]	50
San Bernardino[6]	50
Ventura[7]	13

Tables IV and V show the final 1987 valve and fitting emissions by county, respectively.

ASSUMPTIONS

1. For wells in similar lease models, the physical and mechanical properties of the wells along with the required maintenance schedule were identical. This "identical nature" allowed the development of one composite set of emission factors for each lease model.

2. The process rate unit for valves and fittings is the "number of active wells." This choice is based upon the assumption that emissions depend not upon the amount of oil or gas produced, but rather on the number of leak points (valves or fittings), which is proportional to the number of wells in operation.

3. The emissions are set to zero for heavy crude oil with an API gravity less than 20 where the gas production equals zero and the oil is not thermally enhanced.[8]

4. The maintenance schedules are as effective at reducing emissions as reported by the districts in Table I.

COMMENTS AND RECOMMENDATIONS

The KVB survey of 1979-80 provided a significant amount of the background information necessary to calculate emission factors for valves and fittings. Because of both time and budgetary constraints, KVB scientists surveyed a limited number of leases from each lease model. Additional leases with a similar number of wells and GOR are represented by a single lease model emission factor.

KVB's data are divided into more than the six distinct lease models. However, the ARB decided to break the lease data into only six categories, creating a small number of generalized

lease classifications, simplifying the data analysis and programing. More classifications for both the GOR and the number of wells would facilitate the development of better emission factors and emission estimates for more specialized types of leases.

Some Districts implement rules for the maintenance of valves and fittings, and should justify the effectiveness of their rules in reducing emissions from these devices. The Air Quality Management Plan (AQMP) rule is not a good indicator of actual emission changes. Before the reduction in valve and fitting emissions from the AQMP maintenance is used, the district should perform an analysis on the maintenance rule effectiveness in 1987. Only Ventura County APCD conducted a detailed analysis in 1987. The South Coast AQMD cites the information in the AQMP for the rule effectiveness. Kern County APCD refers to the AQMP for their estimation of the rule effectiveness, but this district has not conducted an analysis on the actual effectiveness in 1987.

CHANGES IN METHODOLOGY

Two changes were made in the 1987 methodology. First, the emissions from valves and fittings for Heavy Crude were set to zero in the 1987 inventory (when the API gravity was less than or equal to 20, the gas production was equal to zero, and the oil was not thermally enhanced). Second, emission reductions from maintenance operations were included in the 1987 inventory.

DIFFERENCES BETWEEN 1983 AND 1987 EMISSION ESTIMATES

On the average, the 1987 oil leases had a lower emission factor per well, leading to lower overall emissions. The 1987 inventory marks the first year in which emission reductions, due to maintenance on valves and fittings, were included, causing a reduction in the per well emission factors. The 1987 emissions were also reduced by setting the emissions from heavy crudes to zero, where gas production equals zero and the oil is not thermally enhanced.

TEMPORAL ACTIVITY

The emissions from valves and fittings are largely the result of leakage from corrosion or improper connection, so on the average the emissions are uniform over time. The annual production activity occurs uniformly, and the emissions are independent of both daily and weekly activity.

SAMPLE CALCULATIONS

Both valve and fitting emissions can be found using a general equation. The more detailed lease model algorithm is examined in the section entitled "Sample Calculations." The following equation shows the number of active wells on a lease multiplied by the lease model algorithm results which are the per well emission factor:

Emissions = (Active Wells on a Lease) x (Per Well Emission Factor)

The following example illustrates the calculation of ROG valve and fitting emissions for Union Oil's Polvadero Lease located in Fresno County. Two active wells are in operation at the lease, and the gas to oil ratio is equal to 334. The GOR and the number of active wells place this lease in Lease Model #1 for emission calculation purposes.

TOTAL REACTIVE ORGANIC GASES (ROG) VALVE EMISSIONS

$$= (\text{Valve Emissions})_{gas} + (\text{Valve Emissions})_{oil}$$

$(\text{Valve Emissions})_{gas} = (\text{No. of Active Wells})\ (\text{Emission Factor})_{gas}$*

$= (2 \text{ wells})\ (1.461 \text{ lbs/day-well})$

$= (2.922 \text{ lbs/day})\ (365 \text{ days/year})\ (1 \text{ ton}/2000 \text{ lbs})$

$= 0.53 \text{ tons/year}$

* Refer to Table II

$(\text{Valve Emissions})_{oil} = (\text{No. of Active Wells}) \times (\text{Emission Factor})_{oil}$*

$= (2 \text{ wells})\ (1.012 \times 10^{-4} + 7.715 \times 10^{-2} \text{ lbs/d-w})$

$= (0.155 \text{ lbs/day})\ (365 \text{ days/year})\ (1 \text{ ton}/2000 \text{ lbs})$

$= 0.03 \text{ tons/year}$

Total Valve Emissions $= 0.53 \text{ tons/year} + 0.03 \text{ tons/year}$

$= \underline{0.56 \text{ tons/year}}$

TOTAL ROG FITTING EMISSIONS

= $(\text{Fitting Emissions})_{gas}$ + $(\text{Fitting Emissions})_{oil}$

$(\text{Fitting Emissions})_{gas}$ = (No. of Active Wells) $(\text{Emission Factor})_{gas}$*

= (2 wells) (0.8746 lbs/day-well)

= (1.75 lbs/day) (365 days/year) (1 ton/2000 lbs)

= 0.32 tons/year

$(\text{Fitting Emissions})_{oil}$ = (No. of Active Wells) $(\text{Emission Factors})_{oil}$*

= (2 wells) (3.335×10^{-2} + 1.175×10^{-1} lbs/d-w)

= (0.302 lbs/day) (365 days/year) (1 ton/2000 lbs)

= 0.06 tons/year

Total Fitting Emissions = 0.32 tons/year + 0.06 tons/year

= <u>0.38 tons/year</u>

* Refer to Tables II and III.

REFERENCES

1. Eaton, W.S. et al., Fugitive Hydrocarbon Emissions from Petroleum Production Operations, American Petroleum Institute, Rockwell International, (March 1980).

2. Dennison, W. J. et al., Emission Characteristics of Crude Oil Production Operations in California, KVB, Inc., (January 1983).

3. Division of Oil and Gas, Department of Conservation, State of California, Division of Oil and Gas Tape, 1987.

4. Paxson, T., Kern County (personal communication 9/89, (805) 861-3682).

5. Kern County APCD, Air Quality Management Plans, 1987.

6. Santos, R., South Coast Air Quality Management District (personal communication 9/89).

7. Cowen, S., Ventura County (personal communication 9/89 (805) 654-5032).

8. Division of Oil and Gas, Department of Conservation, State of California, 73rd Annual Report of the State Oil and Gas Supervisor, 1987.

PREPARED BY

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Table II
Valve Emission Factors

Lease Model	Service	TOG Emission Factor (lbs/day-well) x 10^{-4}	ROG Emission Factor (lbs/day-well) x 10^{-4}
Model #1	Gas	36250.00	14610.00
	Liquid	2.511	1.012
	Mixture	1914.00	771.50
	Condensate	0.00	0.00
Model #2	Gas	17410.00	7018.00
	Liquid	2.484	1.001
	Mixture	488.60	196.90
	Condensate	0.00	0.00
Model #3	Gas	159.10	64.10
	Liquid	0.6658	0.26830
	Mixture	394.80	159.10
	Condensate	0.00	0.00
Model #4	Gas	114600.00	46170.00
	Liquid	3.109	1.253
	Mixture	776.40	312.90
	Condensate	0.00	0.00
Model #5	Gas	21220.00	8550.00
	Liquid	1.302	0.5247
	Mixture	855.30	344.70
	Condensate	0.00	0.00
Model #6	Gas	43080.00	17360.00
	Liquid	0.2164	0.87190
	Mixture	613.90	247.40
	Condensate	0.00	0.00

Model #1: Number of wells on the lease is less than 10 and the GOR is less than 500.

Model #2: Number of wells on the lease is between 10 and 50 and the GOR is less than 500.

Model #3: Number of wells on the lease is greater than 50 and the GOR is less than 500.

Model #4: Number of wells on the lease is less than 10 and the GOR is greater than 500.

Model #5: Number of wells on the lease is between 10 and 50 and the GOR is greater than 500.

Model #6: Number of wells on the lease is greater than 50 and the GOR is greater than 500.

Table III
Fitting Emission Factors

Lease Model	Service	TOG Emission Factor (lbs/day-well)	ROG Emission Factor (lbs/day-well)
Model #1	Gas	2.170×10^{0}	8.746×10^{-1}
	Liquid	8.275×10^{-2}	3.335×10^{-2}
	Mixture	2.916×10^{-1}	1.175×10^{-1}
	Condensate	0.000×10^{0}	0.000×10^{0}
Model #2	Gas	1.481×10^{0}	5.968×10^{-1}
	Liquid	1.037×10^{-7}	4.180×10^{-8}
	Mixture	3.122×10^{-2}	1.258×10^{-2}
	Condensate	0.000×10^{0}	0.000×10^{0}
Model #3	Gas	4.266×10^{-2}	1.719×10^{-2}
	Liquid	2.486×10^{-3}	1.002×10^{-3}
	Mixture	1.271×10^{-1}	5.122×10^{-2}
	Condensate	1.017×10^{-5}	4.098×10^{-6}
Model #4	Gas	5.218×10^{0}	2.103×10^{0}
	Liquid	1.898×10^{-7}	7.650×10^{-8}
	Mixture	2.354×10^{-1}	9.486×10^{-2}
	Condensate	0.000×10^{0}	0.000×10^{0}
Model #5	Gas	4.489×10^{0}	1.809×10^{0}
	Liquid	7.432×10^{-3}	2.995×10^{-3}
	Mixture	4.727×10^{-1}	1.905×10^{-1}
	Condensate	0.000×10^{0}	0.000×10^{0}
Model #6	Gas	6.367×10^{0}	2.566×10^{0}
	Liquid	5.538×10^{-9}	2.232×10^{-9}
	Mixture	2.945×10^{-2}	1.187×10^{-2}
	Condensate	6.213×10^{-5}	2.504×10^{-5}

Model #1: Number of wells on the lease is less than 10 and the GOR is less than 500.

Model #2: Number of wells on the lease is between 10 and 50 and the GOR is less than 500.

Model #3: Number of wells on the lease is greater than 50 and the GOR is less than 500.

Model #4: Number of wells on the lease is less than 10 and the GOR is greater than 500.

Model #5: Number of wells on the lease is between 10 and 50 and the GOR is greater than 500.

Model #6: Number of wells on the lease is greater than 50 and the GOR is greater than 500.

Table IV
1987 Area Source Emissions
Activity: Oil & Gas Extraction
Process: Petroleum & Related
Entrainment: Process Loss
Dimn: Primary / Secondary Operation Fugitive
CES: 81968
Process Rate Unit: Well -Year

AB	County	Process Rates	TOG Emis. (Tons / Year)	CO Emis. (Tons / Year)	NOX Emis. (Tons / Year)	SOX Emis. (Tons / Year)	PM Emis. (Tons / Year)
NC	HUMBOLDT	38	40.60	0.00	0.00	0.00	0.00
	SONOMA	10	2.20	0.00	0.00	0.00	0.00
NCC	MONTEREY	590	59.50	0.00	0.00	0.00	0.00
	SAN BENITO	54	32.30	0.00	0.00	0.00	0.00
SC	LOS ANGELES	5779	1370.90	0.00	0.00	0.00	0.00
	ORANGE	2982	664.20	0.00	0.00	0.00	0.00
	RIVERSIDE	19	11.30	0.00	0.00	0.00	0.00
	SAN BERNARDINO	40	11.50	0.00	0.00	0.00	0.00
SCC	SAN LUIS OBISPO	337	191.50	0.00	0.00	0.00	0.00
	SANTA BARBARA	1481	1108.00	0.00	0.00	0.00	0.00
	VENTURA	2607	1618.50	0.00	0.00	0.00	0.00
SF	ALAMEDA	3928	3.28	0.00	0.00	0.00	0.00
	CONTRA COSTA	110480	89.79	0.00	0.00	0.00	0.00
	SAN MATEO	35851	29.20	0.00	0.00	0.00	0.00
	SANTA CLARA	5417	4.38	0.00	0.00	0.00	0.00
SJV	FRESNO	2588	556.50	0.00	0.00	0.00	0.00
	KERN	35120	4779.00	0.00	0.00	0.00	0.00
	KINGS	162	138.10	0.00	0.00	0.00	0.00
	MADERA	48	56.20	0.00	0.00	0.00	0.00
	MERCED	3	6.60	0.00	0.00	0.00	0.00
	SAN JOAQUIN	159	238.30	0.00	0.00	0.00	0.00
	TULARE	80	41.70	0.00	0.00	0.00	0.00
SV	BUTTE	25	24.70	0.00	0.00	0.00	0.00
	COLUSA	236	442.70	0.00	0.00	0.00	0.00
	GLENN	225	384.00	0.00	0.00	0.00	0.00
	SACRAMENTO	188	232.50	0.00	0.00	0.00	0.00
	SOLANO	370	593.70	0.00	0.00	0.00	0.00
	SUTTER	254	421.60	0.00	0.00	0.00	0.00
	TEHAMA	88	156.10	0.00	0.00	0.00	0.00
	YOLO	176	270.60	0.00	0.00	0.00	0.00
TOTAL		209335	13579.45	0.00	0.00	0.00	0.00

Fraction of Reactive Organic Gases (FROG): .4030

(Reactive Organic Gases (ROG) Emissions = TOG X FROG)

Fraction of PM10 (FRPM10): .6100

(PM10 Emissions = PM X FRPM10)

Table V
1987 Area Source Emissions
Activity: Oil & Gas Extraction
Process: Petroleum & Related
Entrainment: Process Loss
Dimn: Primary / Secondary Operation Fugitive
CES: 81976
Process Rate Unit: Well-Year

AB	County	Process Rate	TOG Emis. (Tons / Year)	CO Emis. (Tons / Year)	NOX Emis. (Tons / Year)	SOX Emis. (Tons / Year)	PM Emis. (Tons / Year)
NC	HUMBOLDT	38	36.20	0.00	0.00	0.00	0.00
	SONOMA	10	1.00	0.00	0.00	0.00	0.00
NCC	MONTEREY	590	50.40	0.00	0.00	0.00	0.00
	SAN BENITO	54	20.40	0.00	0.00	0.00	0.00
SC	LOS ANGELES	5779	1144.00	0.00	0.00	0.00	0.00
	ORANGE	2982	651.40	0.00	0.00	0.00	0.00
	RIVERSIDE	19	5.70	0.00	0.00	0.00	0.00
	SAN BERNARDINO	40	7.90	0.00	0.00	0.00	0.00
SCC	SAN LUIS OBISPO	337	271.60	0.00	0.00	0.00	0.00
	SANTA BARBARA	1481	1126.40	0.00	0.00	0.00	0.00
	VENTURA	2607	1525.80	0.00	0.00	0.00	0.00
SF	ALAMEDA	3928	3.28	0.00	0.00	0.00	0.00
	CONTRA COSTA	110480	89.79	0.00	0.00	0.00	0.00
	SAN MATEO	35851	29.20	0.00	0.00	0.00	0.00
	SANTA CLARA	5417	4.38	0.00	0.00	0.00	0.00
SJV	FRESNO	2588	433.40	0.00	0.00	0.00	0.00
	KERN	35120	5259.30	0.00	0.00	0.00	0.00
	KINGS	162	84.40	0.00	0.00	0.00	0.00
	MADERA	48	36.30	0.00	0.00	0.00	0.00
	MERCED	3	3.10	0.00	0.00	0.00	0.00
	SAN JOAQUIN	159	139.30	0.00	0.00	0.00	0.00
	TULARE	80	24.20	0.00	0.00	0.00	0.00
SV	BUTTE	25	20.20	0.00	0.00	0.00	0.00
	COLUSA	236	221.70	0.00	0.00	0.00	0.00
	GLENN	225	195.00	0.00	0.00	0.00	0.00
	SACRAMENTO	188	185.00	0.00	0.00	0.00	0.00
	SOLANO	370	356.20	0.00	0.00	0.00	0.00
	SUTTER	254	230.10	0.00	0.00	0.00	0.00
	TEHAMA	88	80.50	0.00	0.00	0.00	0.00
	YOLO	176	136.00	0.00	0.00	0.00	0.00
TOTAL		209335	12372.15	0.00	0.00	0.00	0.00

Fraction of Reactive Organic Gases (FROG): .4030
(Reactive Organic Gases (ROG) Emissions = TOG X FROG)
Fraction of PM10 (FRPM10): .6100
(PM10 Emissions = PM X FRPM10)